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(51) INT CL:  
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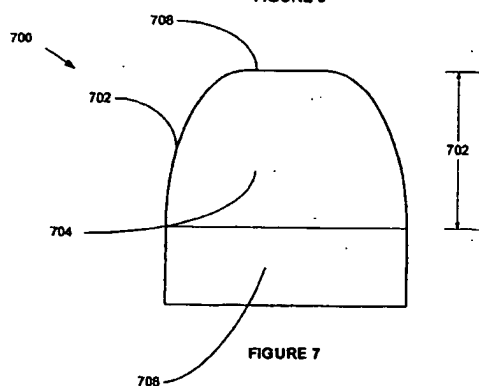
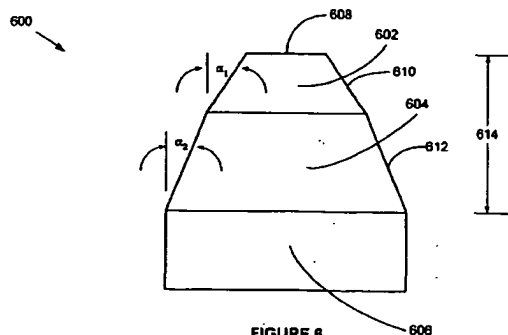
(52) UK CL (Edition X):  
E1F FLA

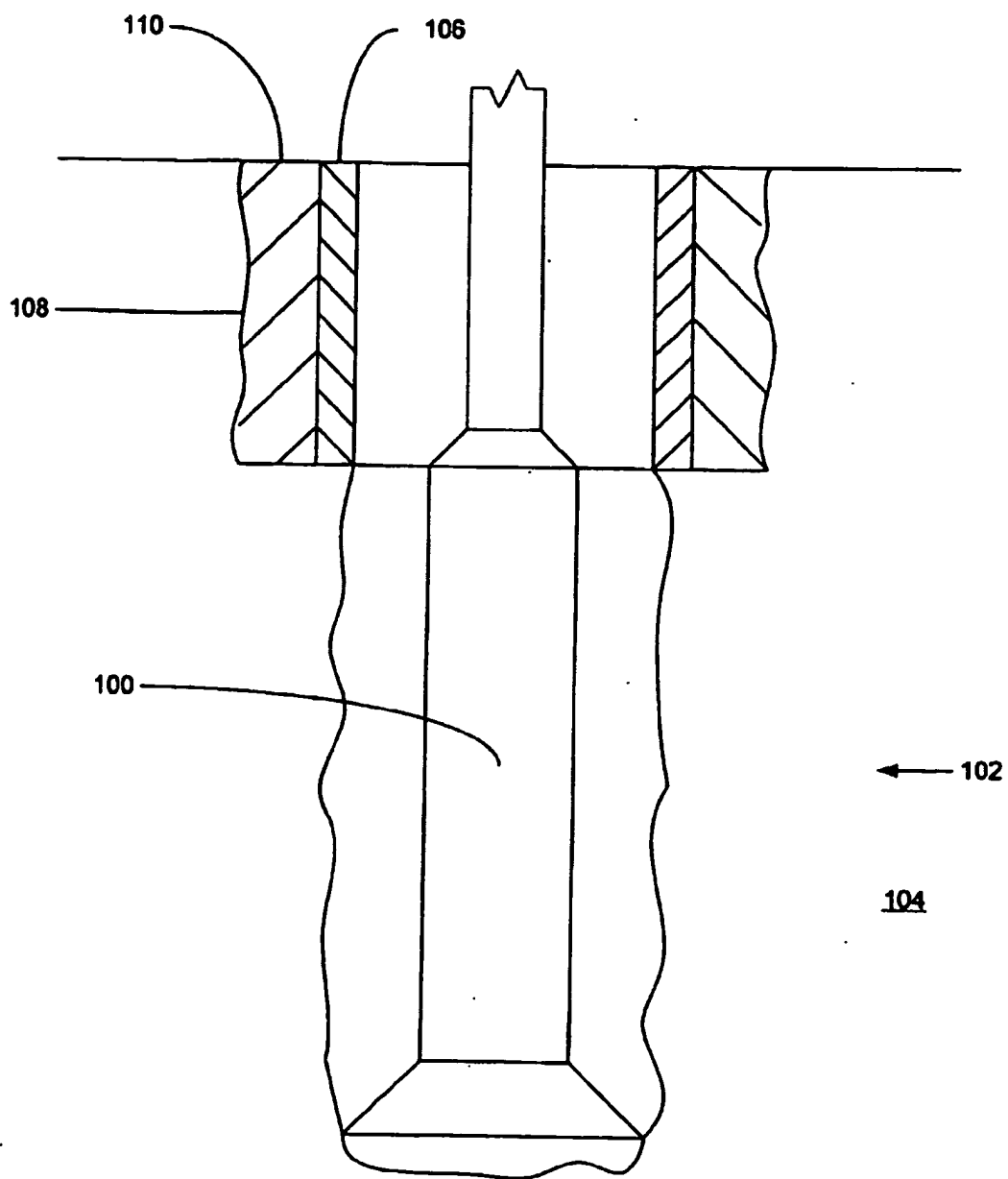
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(58) Field of Search:  
INT CL B21D, E21B  
Other: EPODOC, WPI

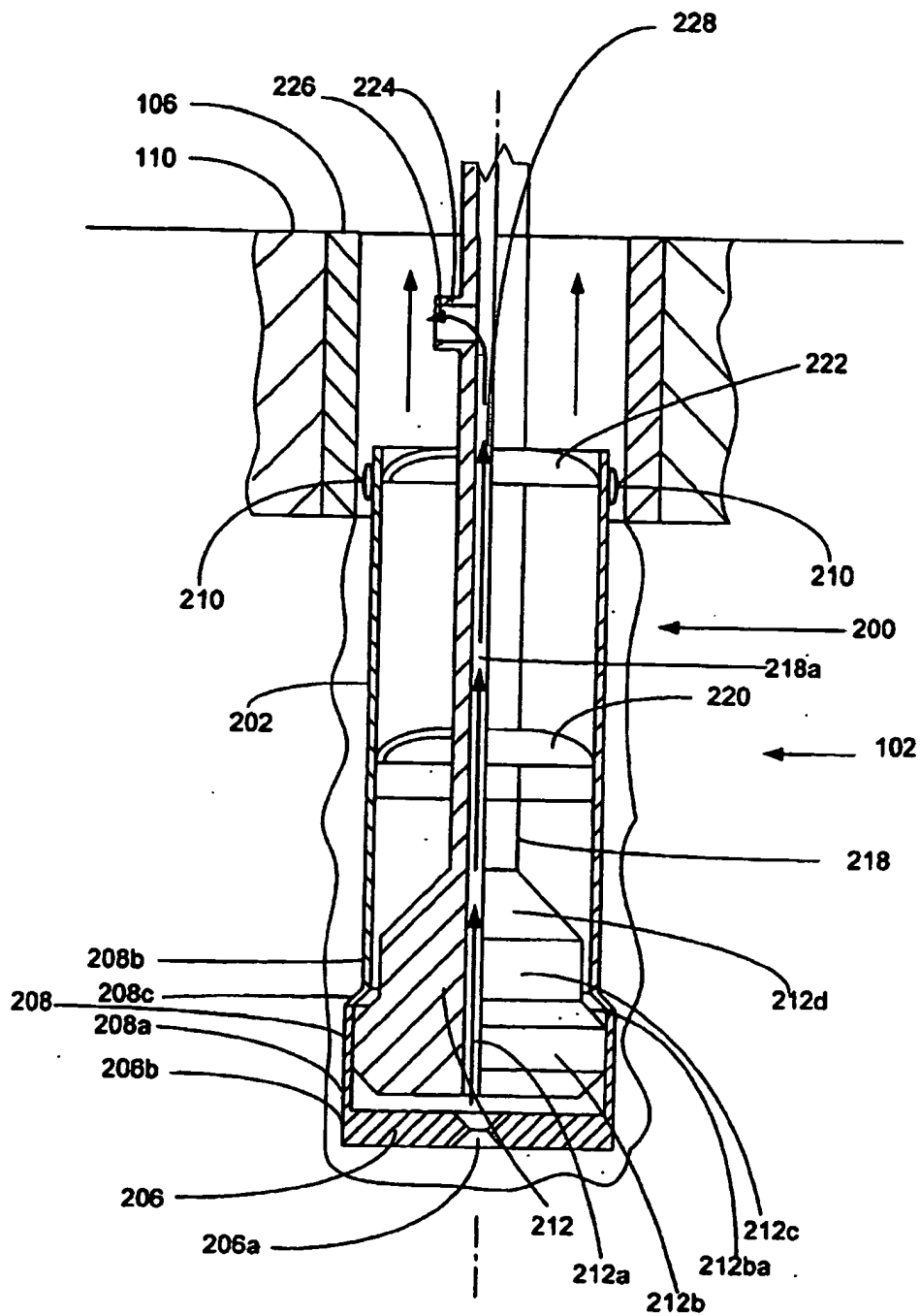
(54) Abstract Title: **An expandable cone or tubular having a coating of tungsten disulfide**

(57) An expansion cone 600 for expanding a tubular includes on one of its surfaces a coating of tungsten disulfide which acts as a solid lubricant. The tungsten disulfide may also be applied to the interior surface of the tubular being expanded. The expansion cone 600 has a first outer surface comprising a first angle of attack 602 from about 8-20 degrees and a second outer surface having an angle of attack 604 from 4-15 degrees. In another embodiment the angle of attack 702 of said surfaces may be described by a parabolic equation.





**FIGURE 1**



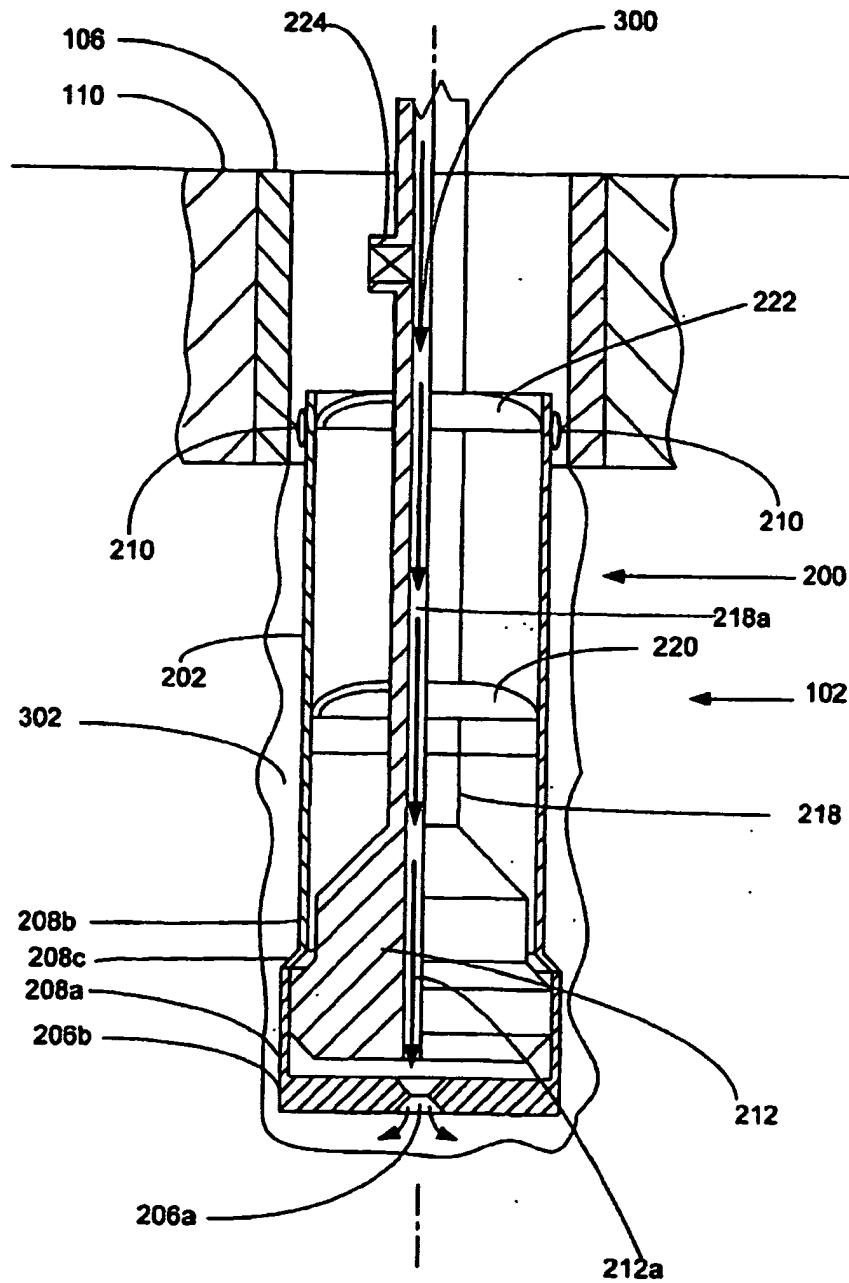
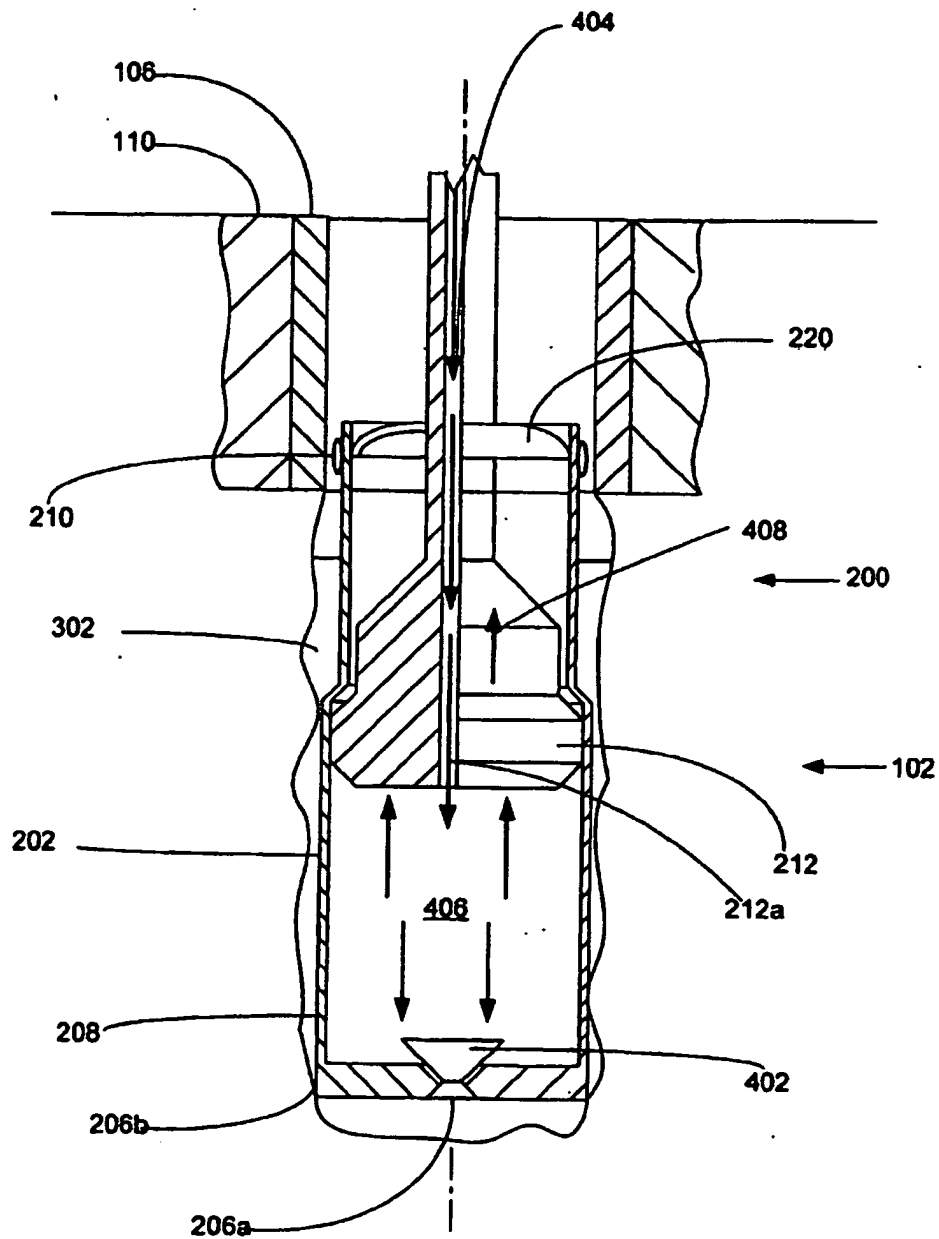
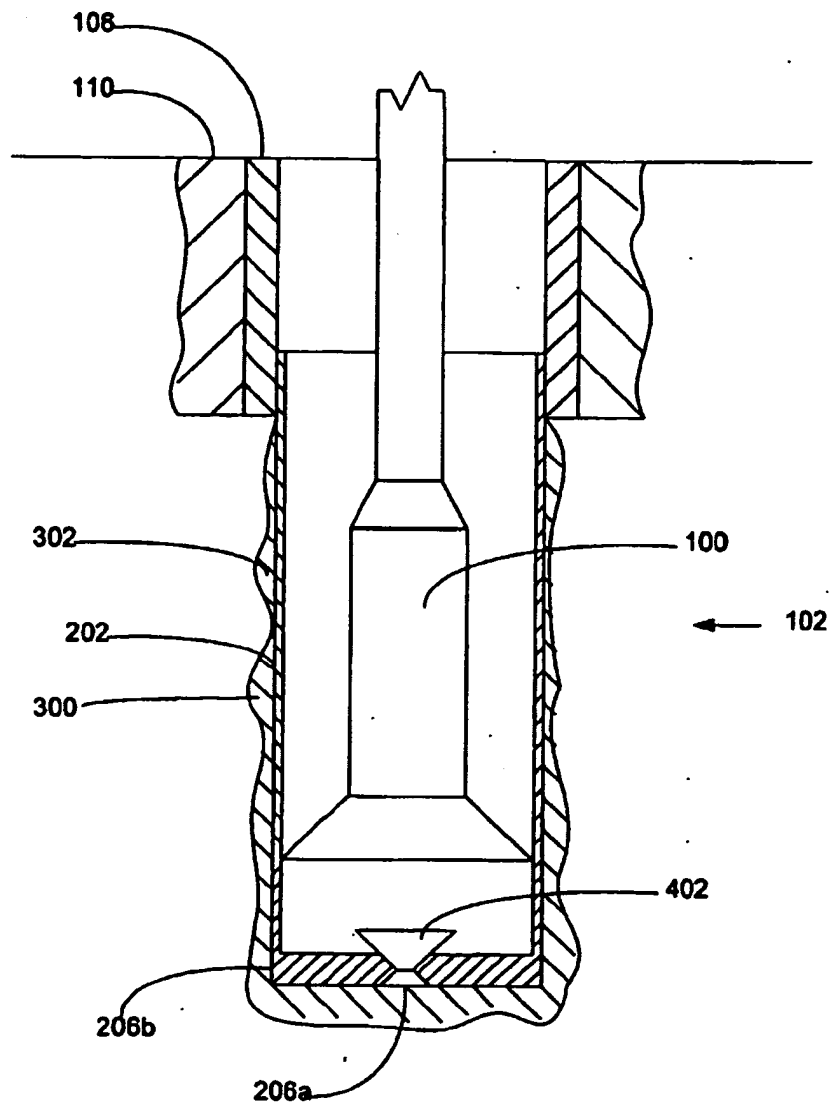


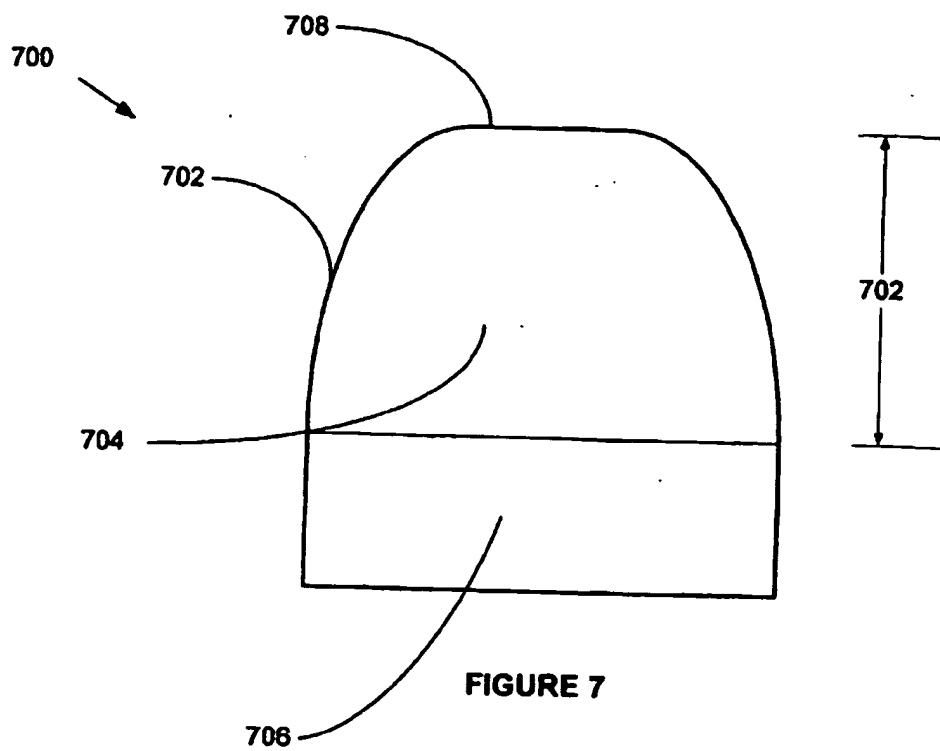
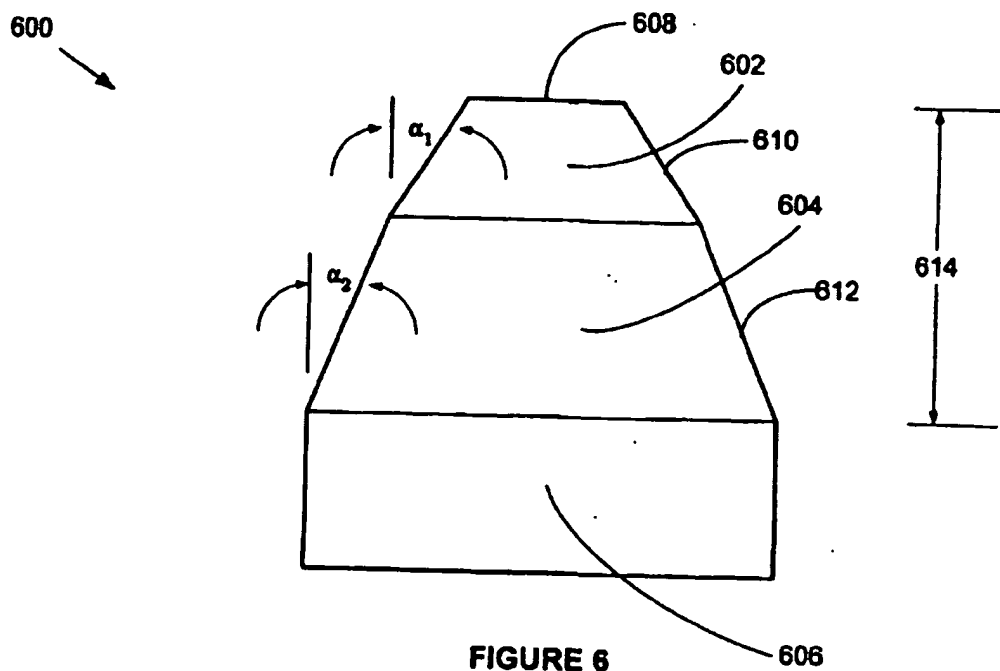
FIGURE 3



**FIGURE 4**



**FIGURE 5**



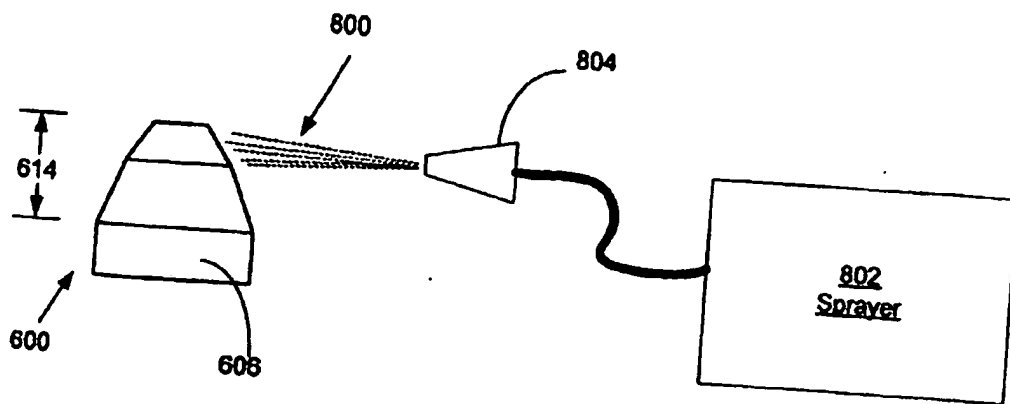


FIGURE 8

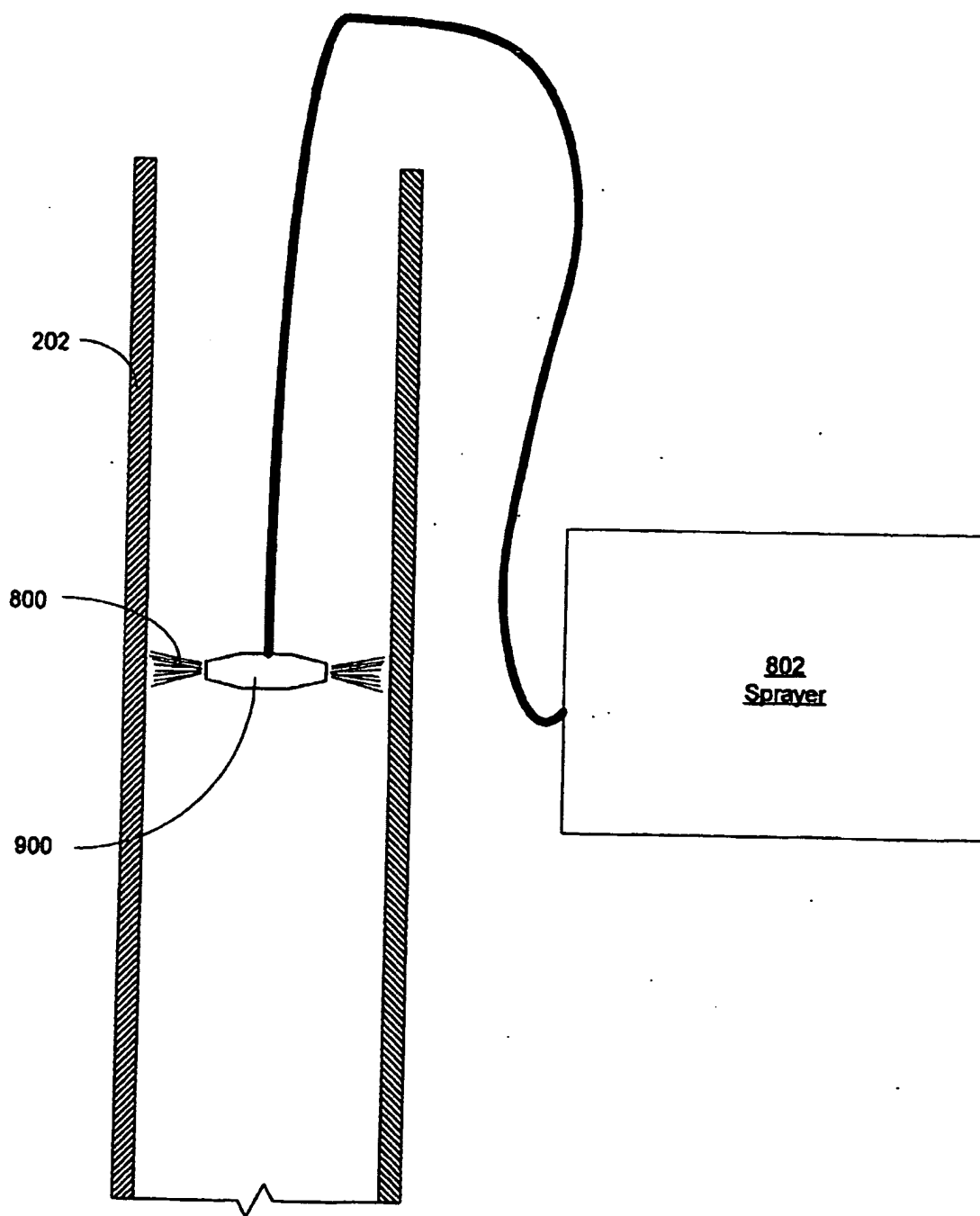


FIGURE 9

**EXPANSION SYSTEM****CROSS REFERENCE TO RELATED APPLICATIONS**

5 This application is a continuation of U.S. patent application serial number 10/199,524, attorney docket number 25791.100, filed on 7/19/2002, which is a continuation of U.S. patent application serial number 09/454,139, attorney docket number 25791.3.02, filed 12/3/1999 (now U.S. Patent 6,497,289, issued 12/24/02) which claimed priority to U.S. provisional patent application serial number 60/111,293, attorney docket no. 25791.3, filed on 12/7/1998, the disclosure of which is incorporated herein by reference.

10 This application is related to the following co-pending applications: (1) U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, which claims priority from provisional application  
15 60/121,702, filed on 2/25/99, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, which claims priority from provisional application 60/119,611, filed on 2/11/99, (4) U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (5) U.S. patent  
20 application serial no. 10/169,434, attorney docket no. 25791.10.04, filed on 7/1/02, which claims priority from provisional application 60/183,546, filed on 2/18/00, (6) U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (7) U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02,  
25 filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (8) U.S. patent number 6,575,240, which was filed as patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, which claims priority from provisional application 60/121,907, filed on 2/26/99, (9) U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on  
30 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (10) U.S. patent application serial no. 09/981,916, attorney docket no. 25791.18, filed on 10/18/01 as a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (11) U.S. patent

number 6,604,763, which was filed as application serial no. 09/559,122, attorney docket no.  
 25791.23.02, filed on 4/26/2000, which claims priority from provisional application 60/131,106,  
 filed on 4/26/99, (12) U.S. patent application serial no. 10/030,593, attorney docket no.  
 25791.25.08, filed on 1/8/02, which claims priority from provisional application 60/146,203, filed  
 5 on 7/29/99, (13) U.S. provisional patent application serial no. 60/143,039, attorney docket no.  
 25791.26, filed on 7/9/99, (14) U.S. patent application serial no. 10/111,982, attorney docket no.  
 25791.27.08, filed on 4/30/02, which claims priority from provisional patent application serial no.  
 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (15) U.S. provisional patent  
 application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (16) U.S.  
 10 provisional patent application serial no. 60/438,828, attorney docket no. 25791.31, filed on  
 1/9/03, (17) U.S. patent number 6,564,875, which was filed as application serial no. 09/679,907,  
 attorney docket no. 25791.34.02, on 10/5/00, which claims priority from provisional patent  
 application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (18) U.S.  
 patent application serial no. 10/089,419, filed on 3/27/02, attorney docket no. 25791.36.03,  
 15 which claims priority from provisional patent application serial no. 60/159,039, attorney docket  
 no. 25791.36, filed on 10/12/1999, (19) U.S. patent application serial no. 09/679,906, filed on  
 10/5/00, attorney docket no. 25791.37.02, which claims priority from provisional patent  
 application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (20) U.S.  
 patent application serial no. 10/303,992, filed on 11/22/02, attorney docket no. 25791.38.07,  
 20 which claims priority from provisional patent application serial no. 60/212,359, attorney docket  
 no. 25791.38, filed on 6/19/2000, (21) U.S. provisional patent application serial no. 60/165,228,  
 attorney docket no. 25791.39, filed on 11/12/1999, (22) U.S. provisional patent application serial  
 no. 60/455,051, attorney docket no. 25791.40, filed on 3/14/03, (23) PCT application  
 US02/2477, filed on 6/26/02, attorney docket no. 25791.44.02, which claims priority from U.S.  
 25 provisional patent application serial no. 60/303,711, attorney docket no. 25791.44, filed on  
 7/6/01, (24) U.S. patent application serial no. 10/311,412, filed on 12/12/02, attorney docket no.  
 25791.45.07, which claims priority from provisional patent application serial no. 60/221,443,  
 attorney docket no. 25791.45, filed on 7/28/2000, (25) U.S. patent application serial no. 10/, filed  
 on 12/18/02, attorney docket no. 25791.46.07, which claims priority from provisional patent  
 30 application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (26) U.S.  
 patent application serial no. 10/322,947, filed on 1/22/03, attorney docket no. 25791.47.03,  
 which claims priority from provisional patent application serial no. 60/233,638, attorney docket  
 no. 25791.47, filed on 9/18/2000, (27) U.S. patent application serial no. 10/406,648, filed on  
 3/31/03, attorney docket no. 25791.48.06, which claims priority from provisional patent

application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (28) PCT  
 application US02/04353, filed on 2/14/02, attorney docket no. 25791.50.02, which claims priority  
 from U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50,  
 filed on 2/20/2001, (29) U.S. patent application serial no. 10/465,835, filed on 6/13/03, attorney  
 5 docket no. 25791.51.06, which claims priority from provisional patent application serial no.  
 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001, (30) U.S. patent application serial  
 no. 10/465,831, filed on 6/13/03, attorney docket no. 25791.52.06, which claims priority from  
 U.S. provisional patent application serial no. 60/259,486, attorney docket no. 25791.52, filed on  
 1/3/2001, (31) U.S. provisional patent application serial no. 60/452,303, filed on 3/5/03, attorney  
 10 docket no. 25791.53, (32) U.S. patent number 6,470,966, which was filed as patent application  
 serial number 09/850,093, filed on 5/7/01, attorney docket no. 25791.55, as a divisional  
 application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial  
 no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from  
 provisional application 60/111,293, filed on 12/7/98, (33) U.S. patent number 6,561,227, which  
 15 was filed as patent application serial number 09/852,026, filed on 5/9/01, attorney docket no.  
 25791.56, as a divisional application of U.S. Patent Number 6,497,289, which was filed as U.S.  
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 which claims priority from provisional application 60/111,293, filed on 12/7/98, (34) U.S. patent  
 application serial number 09/852,027, filed on 5/9/01, attorney docket no. 25791.57, as a  
 20 divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent  
 Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which  
 claims priority from provisional application 60/111,293, filed on 12/7/98, (35) PCT Application  
 US02/25608, attorney docket no. 25791.58.02, filed on 8/13/02, which claims priority from  
 provisional application 60/318,021, filed on 9/7/01, attorney docket no. 25791.58, (36) PCT  
 25 Application US02/24399, attorney docket no. 25791.59.02, filed on 8/1/02, which claims priority  
 from U.S. provisional patent application serial no. 60/313,453, attorney docket no. 25791.59,  
 filed on 8/20/2001, (37) PCT Application US02/29856, attorney docket no. 25791.60.02, filed  
 on 9/19/02, which claims priority from U.S. provisional patent application serial no. 60/326,886,  
 attorney docket no. 25791.60, filed on 10/3/2001, (38) PCT Application US02/20256, attorney  
 30 docket no. 25791.61.02, filed on 6/28/02, which claims priority from U.S. provisional patent  
 application serial no. 60/303,740, attorney docket no. 25791.61, filed on 7/6/2001, (39) U.S.  
 patent application serial no. 09/962,469, filed on 9/25/01, attorney docket no. 25791.62, which  
 is a divisional of U.S. patent application serial no. 09/523,488, attorney docket no. 25791.11.02,  
 filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on

3/11/99, (40) U.S. patent application serial no. 09/962,470, filed on 9/25/01, attorney docket no. 25791.63, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (41) U.S. patent application serial no. 09/962,471, filed on 9/25/01, attorney docket no. 25791.64, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (42) U.S. patent application serial no. 09/962,467, filed on 9/25/01, attorney docket no. 25791.65, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (43) U.S. patent application serial no. 09/962,468, filed on 9/25/01, attorney docket no. 25791.66, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (44) PCT application US 02/25727, filed on 8/14/02, attorney docket no. 25791.67.03, which claims priority from U.S. provisional patent application serial no. 60/317,985, attorney docket no. 25791.67, filed on 9/6/2001, and U.S. provisional patent application serial no. 60/318,388, attorney docket no. 25791.67.02, filed on 9/10/2001, (45) PCT application US 02/39425, filed on 12/10/02, attorney docket no. 25791.68.02, which claims priority from U.S. provisional patent application serial no. 60/343,674, attorney docket no. 25791.68, filed on 12/27/2001, (46) U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, which is a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (47) U.S. utility patent application serial no. 10/516,467, attorney docket no. 25791.70, filed on 12/10/01, which is a continuation application of U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, which is a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (48) PCT application US 03/00609, filed on 1/9/03, attorney docket no. 25791.71.02, which claims priority from U.S. provisional patent application serial no. 60/357,372, attorney docket no. 25791.71, filed on 2/15/02, (49) U.S. patent application serial no. 10/074,703, attorney docket no. 25791.74, filed on 2/12/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority

from provisional application 60/121,841, filed on 2/26/99, (50) U.S. patent application serial no. 10/074,244, attorney docket no. 25791.75, filed on 2/12/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application

5 60/121,841, filed on 2/26/99, (51) U.S. patent application serial no. 10/076,660, attorney docket no. 25791.76, filed on 2/15/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (52) U.S. patent application serial no. 10/076,661, attorney docket no. 25791.77, filed on 2/15/02,

10 which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (53) U.S. patent application serial no. 10/076,659, attorney docket no. 25791.78, filed on 2/15/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket

15 no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (54) U.S. patent application serial no. 10/078,928, attorney docket no. 25791.79, filed on 2/20/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (55)

20 U.S. patent application serial no. 10/078,922, attorney docket no. 25791.80, filed on 2/20/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (56) U.S. patent application serial no. 10/078,921, attorney docket no. 25791.81, filed on 2/20/02, which is a divisional of U.S. patent

25 number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (57) U.S. patent application serial no. 10/261,928, attorney docket no. 25791.82, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on

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#### **BACKGROUND OF THE INVENTION**

The present disclosure relates generally to wellbore casings, and in particular to wellbore casings that are formed using expandable tubing.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

30 Figure 1 is an illustration of a conventional method for drilling a borehole in a subterranean formation.

Figure 2 is an illustration of a device for coupling an expandable tubular member to an existing tubular member.

Figure 3 is an illustration of a hardenable fluidic sealing material being pumped down the device of Figure 2.

Figure 4 is an illustration of the expansion of an expandable tubular member using the expansion device of Figure 2.

5        Figure 5 is an illustration of the completion of the radial expansion and plastic deformation of an expandable tubular member.

Figure 6 is a side view of an exemplary embodiment of an expansion device of Figure 2.

10       Figure 7 is a side view of another exemplary embodiment of an expansion device of Figure 2.

Figure 8 is an illustration of a method of applying tungsten disulfide to an expansion device of Figure 2.

Figure 9 is an illustration of a method of applying tungsten disulfide to the interior surface of the expandable tubular member of Figure 2.

#### 15        **DETAILED DESCRIPTION OF THE DRAWINGS**

Referring initially to Figure 1, a conventional device 100 for drilling a borehole 102 in a subterranean formation 104 is shown. The borehole 102 may be lined with a casing 106 at the top portion of its length. An annulus 108 formed between the casing 106 and the formation 104 may be filled with a sealing material 110, such as, for example, cement. In an exemplary  
20       embodiment, the device 100 may be operated in a conventional manner to extend the length of the borehole 102 beyond the casing 106.

Referring now to Figure 2, a device 200 for coupling an expandable tubular member 202 to an existing tubular member, such as, for example, the existing casing 106, is shown. The device 200 includes a shoe 206 that defines a centrally positioned valveable passage 206a adapted to receive, for example, a ball, plug or other similar device for closing the passage. An  
25       end of the shoe 206b is coupled to a lower tubular end 208a of a tubular launcher assembly 208 that includes the lower tubular end, an upper tubular end 208b, and a tapered tubular transition member 208c. The lower tubular end 208a of the tubular launcher assembly 208 has a greater inside diameter than the inside diameter of the upper tubular end 208b. The tapered tubular  
30       transition member 208c connects the lower tubular end 208a and the upper tubular end 208b. The upper tubular end 208b of the tubular launcher assembly 208 is coupled to an end of the expandable tubular member 202. One or more seals 210 are coupled to the outside surface of the other end of the expandable tubular member 202.

An expansion device 212 is centrally positioned within and mates with the tubular launcher assembly 208. The expansion device 212 defines a centrally positioned fluid pathway 212a, and includes a lower section 212b, a middle section 212c, and an upper section 212d. The lower section 212b of the expansion device 212 defines an inclined expansion surface 212ba that supports the tubular launcher assembly 208 by mating with the tapered tubular transition member 208c of the tubular launcher assembly. The upper section 212d of the expansion device 212 is coupled to an end of a tubular member 218 that defines a fluid pathway 218a. The fluid pathway 218a of the tubular member 218 is fluidically coupled to the fluid pathway 212a defined by the expansion device 212. One or more spaced apart cup seals 220 and 222 are coupled to the outside surface of the tubular member 218 for sealing against the interior surface of the expandable tubular member 202. In an exemplary embodiment, cup seal 222 is positioned near a top end of the expandable tubular member 202. A top fluid valve 224 is coupled to the tubular member 218 above the cup seal 222 and defines a fluid pathway 226 that is fluidically coupled to the fluid pathway 218a.

During operation of the device 200, as illustrated in Figure 2, the device 200 is initially lowered into the borehole 102. In an exemplary embodiment, during the lowering of the device 200 into the borehole 102, a fluid 228 within the borehole 102 passes upwardly through the device 200 through the valveable passage 206a into the fluid pathway 212a and 218a and out of the device 200 through the fluid pathway 226 defined by the top fluid valve 224.

Referring now to Figure 3, in an exemplary embodiment, a hardenable fluidic sealing material 300, such as, for example, cement, is then pumped down the fluid pathway 218a and 212a and out through the valveable passage 206a into the borehole 102 with the top fluid valve 224 in a closed position. The hardenable fluidic sealing material 300 thereby fills an annular space 302 between the borehole 102 and the outside diameter of the expandable tubular member 202.

Referring now to Figure 4, a plug 402 is then injected with a fluidic material 404. The plug thereby fits into and closes the valveable passage 206a to further fluidic flow. Continued injection of the fluidic material 404 then pressurizes a chamber 406 defined by the shoe 206, the bottom of the expansion device 212, and the walls of the launcher assembly 208 and the expandable tubular member 202. Continued pressurization of the chamber 406 then displaces the expansion device 212 in an upward direction 408 relative to the expandable tubular member 202 thereby causing radial expansion and plastic deformation of the launcher assembly 208 and the expandable tubular member.

Referring now to Figure 5, the radial expansion and plastic deformation of the expandable tubular member 202 is then completed and the expandable tubular member is coupled to the existing casing 106. The hardenable fluidic sealing material 300, such as, for example, cement fills the annulus 302 between the expandable tubular member 202 and the borehole 102. The device 200 has been withdrawn from the borehole and a conventional device 100 for drilling the borehole 102 may then be utilized to drill out the shoe 206 and continue drilling the borehole 102, if desired.

Referring now to Figure 6, an expansion cone 600 defines an upper cone 602, a middle cone 604, and a lower tubular end 606. The upper cone 602 has a leading surface 608 and an outer inclined surface 610 that defines an angle  $\alpha_1$ . The middle cone 604 has an outer inclined surface 612 that defines an angle  $\alpha_2$ . In an exemplary embodiment, the angle  $\alpha_1$  is greater than the angle  $\alpha_2$ . The outer inclined surfaces 610 and 612 together form the expansion surfaces 614 that upon displacement of the expansion cone 600 relative to the expandable tubular member 202 radially expand and plastically deform the expandable tubular member.

Referring now to Figure 7, an exemplary embodiment of an expansion cone 700 with an outside expansion surface 702 defining a parabolic equation, is shown. The expansion cone 700 has an upper expansion section 704 and a lower tubular end 706. The upper expansion section 704 has a leading surface 708 and the outside expansion surface 702 defined by a parabolic equation.

In an exemplary embodiment, the expansion device 212 consists of one or more of the expansion devices 600 and 700.

Referring now to Figure 8, in an exemplary embodiment, a method of applying tungsten disulfide 800 to the expansion cone 600 is shown. Tungsten disulfide powder 800 is sprayed onto the expansion surfaces 614 and the circumferential surface of the lower tubular end 606 of the expansion cone 600 of Figure 6 through the use of a sprayer 802, such as, for example, a sandblast sprayer, and a nozzle 804. In an exemplary embodiment, the tungsten disulfide 800 forms a bond with the surface of the expansion cone 600.

In an exemplary embodiment, tungsten disulfide is applied to the outside expansion surface 702 of the expansion cone 700.

Referring now to Figure 9, in an exemplary embodiment, a method of applying tungsten disulfide 800 to the interior of the expandable tubular member 202 is shown. Tungsten disulfide powder 800 is sprayed onto the interior surface of expandable tubular member 202 through the use of a sprayer 802, such as, for example, a sandblast sprayer, and a nozzle 900. In an

exemplary embodiment, the tungsten disulfide 800 forms a bond with the interior surface of the expandable tubular member 202.

Alternative methods of applying tungsten disulfide include, but are not limited to, mixing the tungsten disulfide powder with a carrier, such as, for example, isopropyl alcohol, and buffing the mixture onto the outside surfaces of the expansion cone.

Reduced expansion and Initiation forces are achieved by the coating of tungsten disulfide on the expansion surface of an expansion device. Alternatively, or in addition to the application of tungsten disulfide to the expansion surface of an expansion device, reduced expansion and initiation forces may also be achieved by the coating of tungsten disulfide on the interior surface of an expandable tubular member.

An expansion device for radially expanding a tubular member has been described that includes a first outer surface comprising a first angle of attack; wherein the first outer surface comprises a tungsten disulfide coating and the first angle of attack ranges from about 8 to 20 degrees. A second outer surface comprising a second angle of attack coupled to the first outer surface; wherein the second outer surface comprises a tungsten disulfide coating; the second angle of attack ranges from about 4 to 15 degrees; and wherein the first angle of attack is greater than the second angle of attack. A rear end is coupled to the second outer surface.

An expandable tubular member for traversing a borehole in a subterranean formation has been described that includes a tungsten disulfide coating applied to the interior surface of the expandable tubular member.

An expansion device for radially expanding a tubular member has been described that includes a first outer surface comprising a first angle of attack; wherein the first outer surface comprises a tungsten disulfide coating. A second outer surface comprising a second angle of attack coupled to the first outer surface; wherein the second outer surface comprises a tungsten disulfide coating. The first angle of attack is greater than the second angle of attack. One or more intermediate outer surfaces are coupled between the first and second outer surfaces; wherein the one or more intermediate outer surfaces comprise a tungsten disulfide coating. The angle of attack of the intermediate outer surfaces continually decreases from the first outer surface to the second outer surface and is defined by a parabolic equation.

An expansion system for radially expanding a tubular member has been described that includes an expansion device comprising a first outer surface comprising a first angle of attack; wherein the first angle of attack ranges from about 8 to 20 degrees. The expansion device further comprises a second outer surface comprising a second angle of attack coupled to the first outer surface; wherein the second angle of attack ranges from about 4 to 15 degrees and

the first angle of attack is greater than the second angle of attack. A rear end is coupled to the second outer surface and there are means for displacing the expansion device relative to the expandable tubular member. A tungsten disulfide coating is applied to at least one of the following surfaces: the interior surface of the expandable tubular member and the first and  
5 second outer surfaces of the expansion device.

An expansion system for radially expanding a tubular member has been described that includes an expansion device comprising a first outer surface comprising a first angle of attack and a second outer surface comprising a second angle of attack coupled to the first outer surface. The first angle of attack is greater than the second angle of attack and the expansion  
10 device further comprises one or more intermediate outer surfaces coupled between the first and second outer surfaces; wherein the angle of attack of the intermediate outer surfaces continually decreases from the first outer surface to the second outer surface. The angle of attack of the outer surfaces is defined by a parabolic equation; and there are means for displacing the expansion device in an expandable tubular member. A tungsten disulfide coating is applied to  
15 at least one of the following surfaces: the interior surface of the expandable tubular member and the first, second, and intermediate outer surfaces of the expansion device.

A method of expanding an expandable tubular member has been described that includes radially expanding at least a portion of the tubular member by extruding at least a portion of the tubular member off of an expansion device; wherein the expansion device  
20 comprises a first outer surface comprising a first angle of attack that ranges from about 8 to 20 degrees. A second outer surface comprising a second angle of attack is coupled to the first outer surface, the second angle of attack ranges from about 4 to 15 degrees and the first angle of attack is greater than the second angle of attack. A tungsten disulfide coating is applied to at least one of the following surfaces: the interior surface of the expandable tubular member and  
25 the first and second outer surfaces of the expansion device. A rear end is coupled to the second outer surface.

A method of expanding an expandable tubular member has been described that includes radially expanding at least a portion of the tubular member by extruding at least a portion of the tubular member off of an expansion device. The expansion device comprises a  
30 first outer surface comprising a first angle of attack, and a second outer surface comprising a second angle of attack is coupled to the first outer surface. The first angle of attack is greater than the second angle of attack; and the expansion device further comprises one or more intermediate outer surfaces coupled between the first and second outer surfaces. A tungsten disulfide coating is applied to at least one of the following surfaces: the interior surface of the

expandable tubular member and the first, second, and intermediate outer surfaces of the expansion device. The angle of attack of the intermediate outer surfaces continually decreases from the first outer surface to the second outer surface, and the angle of attack of the outer surfaces is defined by a parabolic equation.

5           Although illustrative embodiments of the invention have been shown and described, a wide range of modification, changes and substitution is contemplated in the foregoing disclosure. In some instances, some features of the present invention may be employed without a corresponding use of the other features, and some steps of the present invention may be executed without a corresponding execution of other steps. Accordingly, all such  
10       modifications, changes and substitutions are intended to be included within the scope of this invention as defined in the following claims, and it is appropriate that the claims be construed broadly and in a manner consistent with the scope of the invention. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures.

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Claims

What is claimed is:

1. An expansion device for radially expanding a tubular member comprising:  
5 a first outer surface comprising a first angle of attack;  
wherein the first outer surface comprises a tungsten disulfide coating.
2. The expansion device of claim 1, further comprising:  
10 a second outer surface comprising a second angle of attack coupled to the first outer surface;  
wherein the first angle of attack is greater than the second angle of attack; and  
wherein the second outer surface comprises a tungsten disulfide coating.
3. The expansion device of claim 1, further comprising:  
15 a rear end coupled to the second outer surface.
4. The expansion device of claim 2, wherein the first angle of attack ranges from about 8 to 20 degrees; and wherein the second angle of attack ranges from about 4 to 15 degrees.
- 20 5. The expansion device of claim 2, further comprising one or more intermediate outer surfaces coupled between the first and second outer surfaces;  
wherein the one or more intermediate outer surfaces comprise a tungsten disulfide coating.
- 25 6. The expansion device of claim 5, wherein the angle of attack of the intermediate outer surfaces continually decreases from the first outer surface to the second outer surface.
7. The expansion device of claim 5, wherein the angle of attack of the intermediate outer surfaces decreases in steps from the first outer surface to the second outer surface.  
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8. The expansion device of claim 5, wherein the angle of attack of the outer surfaces is defined by a parabolic equation.
9. An expansion device for radially expanding a tubular member comprising:  
35 a first outer surface comprising a first angle of attack;

- wherein the first outer surface comprises a tungsten disulfide coating;  
wherein the first angle of attack ranges from about 8 to 20 degrees;  
a second outer surface comprising a second angle of attack coupled to the first outer surface;
- 5 wherein the second outer surface comprises a tungsten disulfide coating;  
wherein the second angle of attack ranges from about 4 to 15 degrees;  
wherein the first angle of attack is greater than the second angle of attack; and  
a rear end coupled to the second outer surface.
- 10 10. An expansion device for radially expanding a tubular member comprising:  
a first outer surface comprising a first angle of attack;  
wherein the first outer surface comprises a tungsten disulfide coating;  
a second outer surface comprising a second angle of attack coupled to the first outer surface;
- 15 wherein the second outer surface comprises a tungsten disulfide coating;  
wherein the first angle of attack is greater than the second angle of attack; and  
further comprising one or more intermediate outer surfaces coupled between the first and second outer surfaces;
- 20 wherein the one or more intermediate outer surfaces comprise a tungsten disulfide coating;  
wherein the angle of attack of the intermediate outer surfaces continually decreases from the first outer surface to the second outer surface; and  
wherein the angle of attack of the outer surfaces is defined by a parabolic equation.
- 25 11. An expandable tubular member for traversing a borehole in a subterranean formation comprising:  
a tungsten disulfide coating applied to the interior surface of the expandable tubular member.
- 30 12. An expansion system for radially expanding a tubular member comprising:  
an expansion device comprising a first outer surface comprising a first angle of attack;  
wherein at least one of the following surfaces comprises a tungsten disulfide coating: the first outer surface of the expansion device and the interior surface of the expandable tubular member; and

means for displacing the expansion device relative to the expandable tubular member.

- 5 13. The expansion system of claim 12, wherein the expansion device further comprises a second outer surface comprising a second angle of attack coupled to the first outer surface;  
wherein the first angle of attack is greater than the second angle of attack; and  
wherein the second outer surface comprises a tungsten disulfide coating.
- 10 14. The expansion device of claim 12, wherein the expansion device further comprises a rear end coupled to the second outer surface.
- 15 15. The expansion system of claim 13, wherein the first angle of attack ranges from about 8 to 20 degrees; and  
wherein the second angle of attack ranges from about 4 to 15 degrees.
- 20 16. The expansion system of claim 13, wherein the expansion device further comprises one or more intermediate outer surfaces coupled between the first and second outer surfaces;  
wherein the one or more intermediate outer surfaces comprise a tungsten disulfide coating.
- 25 17. The expansion system of claim 16, wherein the angle of attack of the intermediate outer surfaces continually decreases from the first outer surface to the second outer surface.
- 30 18. The expansion system of claim 16, wherein the angle of attack of the intermediate outer surfaces decreases in steps from the first outer surface to the second outer surface.
19. The expansion system of claim 16, wherein the angle of attack of the outer surfaces is defined by a parabolic equation.
20. An expansion system for radially expanding a tubular member comprising:  
an expansion device comprising a first outer surface comprising a first angle of attack;  
wherein the first angle of attack ranges from about 8 to 20 degrees;

a second outer surface comprising a second angle of attack coupled to the first outer surface;

wherein the second angle of attack ranges from about 4 to 15 degrees;

wherein the first angle of attack is greater than the second angle of attack; and

5 a rear end coupled to the second outer surface; and

means for displacing the expansion device relative to the expandable tubular member, wherein at least one of the following surfaces comprises a tungsten disulfide coating: the first and second outer surfaces of the expansion device and the interior surface of the expandable tubular member.

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21. An expansion system for radially expanding a tubular member comprising:  
an expansion device comprising a first outer surface comprising a first angle of attack;  
a second outer surface comprising a second angle of attack coupled to the first outer surface;

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wherein the first angle of attack is greater than the second angle of attack; and  
further comprising one or more intermediate outer surfaces coupled between the first and second outer surfaces;

wherein the angle of attack of the intermediate outer surfaces continually decreases from the first outer surface to the second outer surface;

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wherein the angle of attack of the outer surfaces is defined by a parabolic equation; and  
means for displacing the expansion device in an expandable tubular member,  
wherein at least one of the following surfaces comprises a tungsten disulfide coating: the first, second, and intermediate outer surfaces of the expansion device and the interior surface of the expandable tubular member.

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22. A method of expanding an expandable tubular member comprising:  
radially expanding at least a portion of the tubular member by extruding at least a portion of the tubular member off of an expansion device;

30 wherein the expansion device comprises a first outer surface comprising a first angle of attack;

wherein a tungsten disulfide coating is applied to at least one of the following surfaces:  
the interior surface of the expandable tubular member and the first outer surface of the expansion device.

23. The method of expanding a tubular member according to claim 22, wherein the expansion device further comprises:  
a second outer surface comprising a second angle of attack coupled to the first outer surface;  
5 wherein the first angle of attack is greater than the second angle of attack; and  
wherein a tungsten disulfide coating is applied to at least one of the following surfaces:  
the interior surface of the expandable tubular member and the first and second outer surfaces of the expansion device.
- 10 24. The method of expanding a tubular member according to claim 22, wherein the expansion device further comprises:  
a rear end coupled to the second outer surface.
- 15 25. The method of expanding a tubular member according to claim 22, wherein the first angle of attack ranges from about 8 to 20 degrees; and wherein the second angle of attack ranges from about 4 to 15 degrees.
- 20 26. The method of expanding a tubular member according to claim 22, wherein the expansion device further comprises one or more intermediate outer surfaces coupled between the first and second outer surfaces;  
wherein a tungsten disulfide coating is applied to at least one of the following surfaces:  
the interior surface of the expandable tubular member and the first, second, and intermediate outer surfaces of the expansion device.
- 25 27. The method of expanding a tubular member according to claim 22, wherein the angle of attack of the intermediate outer surfaces continually decreases from the first outer surface to the second outer surface.
- 30 28. The method of expanding a tubular member according to claim 22, wherein the angle of attack of the intermediate outer surfaces decreases in steps from the first outer surface to the second outer surface.
29. The method of expanding a tubular member according to claim 22, wherein the angle of attack of the outer surfaces is defined by a parabolic equation.

30. A method of expanding an expandable tubular member comprising:  
radially expanding at least a portion of the tubular member by extruding at least a portion  
of the tubular member off of an expansion device;  
5 wherein the expansion device comprises a first outer surface comprising a first angle of  
attack;  
wherein the first angle of attack ranges from about 8 to 20 degrees;  
a second outer surface comprising a second angle of attack coupled to the first outer  
surface;  
10 wherein a tungsten disulfide coating is applied to at least one of the following surfaces:  
the interior surface of the expandable tubular member and the first and second  
outer surfaces of the expansion device;  
wherein the second angle of attack ranges from about 4 to 15 degrees;  
wherein the first angle of attack is greater than the second angle of attack; and  
15 a rear end coupled to the second outer surface.
31. A method of expanding an expandable tubular member comprising:  
radially expanding at least a portion of the tubular member by extruding at least a portion  
of the tubular member off of an expansion device;  
20 wherein the expansion device comprises a first outer surface comprising a first angle of  
attack;  
a second outer surface comprising a second angle of attack coupled to the first outer  
surface;  
wherein the first angle of attack is greater than the second angle of attack; and  
25 further comprising one or more intermediate outer surfaces coupled between the first  
and second outer surfaces;  
wherein a tungsten disulfide coating is applied to at least one of the following surfaces:  
the interior surface of the expandable tubular member and the first, second, and  
intermediate outer surfaces of the expansion device;  
30 wherein the angle of attack of the intermediate outer surfaces continually decreases  
from the first outer surface to the second outer surface; and  
wherein the angle of attack of the outer surfaces is defined by a parabolic equation.

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**Examiner:** Dr Lyndon Ellis

**Claims searched:** 1-10, 12-31

**Date of search:** 23 April 2007

## Patents Act 1977: Search Report under Section 17

### Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
Y	1, 3, 12, 14 at least	US 2003/0159764 A1 (Goto) Note the use of tungsten disulfide as a lubricant - see claim 5
Y	1, 3, 12, 14 at least	WO 96/10710 A1 (Tsuru) Note the use of tungsten disulfide as a lubricant
Y	1, 3, 12, 14 at least	EP 1306519 A3 (Gano) Note the use of a solid lubricant on an expansion cone - see paragraph 0071
Y	1, 3, 12, 14 at least	US 2004/0231843 A1 (Simpson) Note the use of a solid lubricant on an expansion member - see paragraph 0020 and 0026
A	-	US 2004/0216506 A1 (Simpson) Note the shape of the cone
A	-	GB 2399837 A (Weatherford/Lamb) Note the shape of the cone

### Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

### Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>x</sup> :

Worldwide search of patent documents classified in the following areas of the IPC

B21D; E21B

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

### International Classification:

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Subclass	Subgroup	Valid From
E21B	0043/10	01/01/2006